PB88-171491

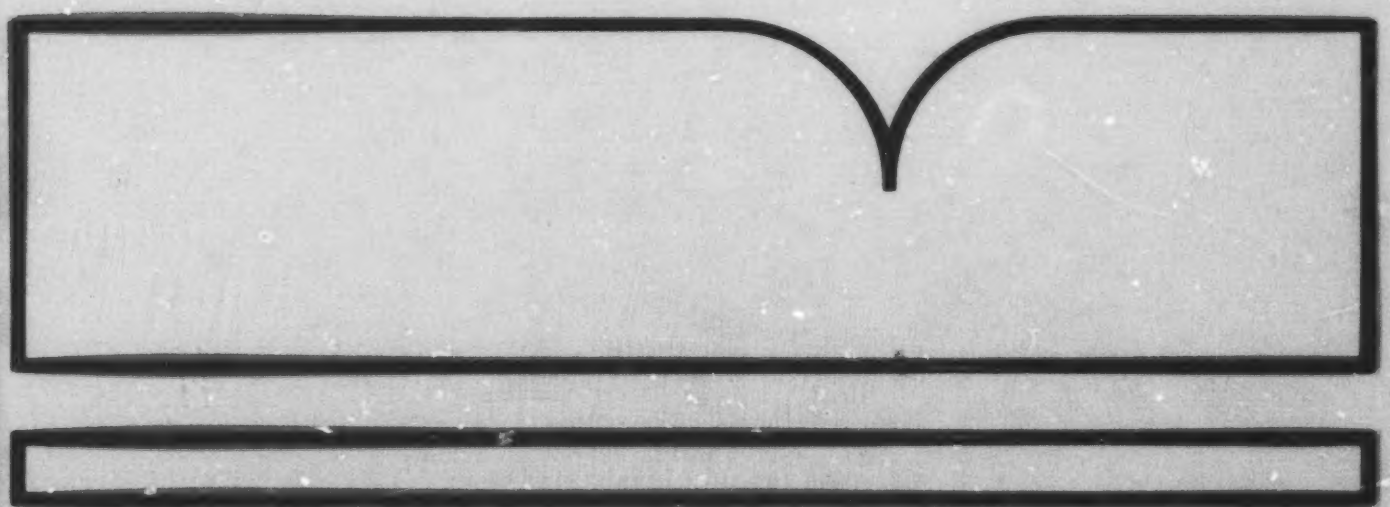
Discussion of Changes to the Industrial Source Complex (ISC) Dispersion Model User's Guide--Second Edition

TRC Environmental Consultants, Inc.
East Hartford, CT

Prepared for

Environmental Protection Agency
Research Triangle Park, NC

Dec 87



U.S. Department of Commerce
National Technical Information Service
NTIS

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. EPA/SW/MT-88/041d	2.	PB88-171491

4. Title and Subtitle
Discussion of Changes to the Industrial Source Complex (ISC) Dispersion Model User's Guide - Second Edition

5. Report Date
December 1987

6.

7. Author(s)
Curtis P. Wagner

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
TRC Environmental Consultants, Inc.
800 Connecticut Boulevard
East Hartford, CT 06108

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C) EPA 68-02-3886
(G) Task No. 60

12. Sponsoring Organization Name and Address
U.S. Environmental Protection Agency
Athospheric Sciences Research Laboratory
Research Triangle Park, NC 27711

13. Type of Report & Period Covered

14.

15. Supplementary Notes
For magnetic tape, see PB88-169487.

16. Abstract (Limit: 200 words)

The User's Network for Applied Modeling of Air Pollution (UNAMAP), Version 6 (Revised 1/88) contains 30 air quality simulation models. These models input emission and meteorological data to calculate projected air pollutant concentrations. UNAMAP contains state-of-the-art dispersion research algorithms funded by the EPA's Office of Air Quality Planning and Standards for Environmental Impact Analysis.

The Industrial Source Complex (ISC) Model has undergone several revisions since first being issued in order to correct and improve technical features and to make the model more appropriate for specific applications. Recent changes to the UNAMAP 6 version of both ISC Short-Term and ISC Long-Term include the ability to model receptors located above ground level ("flagpole" receptors) and a revised building downwash treatment method. These changes are covered are covered in this addendum.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL
INFORMATION SERVICE
SPRINGFIELD, VA. 22161

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages
	20. Security Class (This Page) UNCLASSIFIED	22. Price

Discussion of Changes to the Industrial Source Complex (ISC) Dispersion Model User's Guide - Second Edition

Contract No. EPA 68-02-3886, Task No. 60

Prepared for:
Russell F. Lee, Project Officer

Source Receptor Analysis Branch (MD-14)
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency

By:
Curtis P. Wagner

TRC Environmental Consultants, Inc.
800 Connecticut Boulevard
East Hartford, Connecticut 06108

December 1987

TABLE OF CONTENTS

SECTION		PAGE
Figures		
Abstract	.....	iii
1.0	INTRODUCTION	1
2.0	DESCRIPTION OF MODIFICATIONS	2
a.	Above Ground ("flagpole") Receptors	2
b.	Revised Building Downwash Treatment	5
3.0	MANUAL REVISIONS	11
4.0	REFERENCES	14

LIST OF FIGURES

FIGURE		PAGE
1-1	Linear Decay Factor, A, as a Function of Effective Plume Height, H_e	7

ABSTRACT

The EPA is involved in updating and revising air quality dispersion models for use in regulatory applications. The revisions are made to correct and improve technical features and to make the models more appropriate for specific applications. The Industrial Source Complex (ISC) Model is one of these models which has undergone several revisions since first being issued (Bowers, et al., 1979). Recent changes to the UNAMAP 6 version of both ISC Short-Term and ISC Long-Term include the ability to model receptors located above ground level ("flagpole" receptors) and a revised building downwash treatment method based on the suggestions of Schulman and Hanna (1986), and of Schulman and Scire (1980).

Previously, the ISC models made the assumptions that receptors were located at ground level. Even for elevated terrain, this assumption simplified the Gaussian equation considerably by reducing the number of multiple reflection terms by a factor of two. However, some situations, occur that may require an air quality modeler to obtain calculated concentration estimates at receptor elevations located above ground level, or "flagpole" receptors. The model has been modified to incorporate these calculations as a user option; this option has long been a feature of the RAM model in UNAMAP.

The original UNAMAP 6 building downwash treatment was a simplified method using only one set of building dimensions for all directions. The method did not consider: 1) a downwash stack's height relative to the building height; 2) reduction in final plume rise, and 3) variations in building to stack geometry as a function of wind direction. These modifications have been incorporated into the model as a user option and as a required input when the regulatory option is selected.

1.0 INTRODUCTION

The Industrial Source Complex (ISC) Dispersion Model combines and enhances various dispersion model algorithms to consider pollutant sources other than emissions from isolated stacks, such as fugitive emissions, aerodynamic wake effects, gravitational settling and dry deposition in assessing the air quality impact of emissions from the wide variety of sources associated with an industrial source complex. The Industrial Source Complex (ISC) Dispersion Model consists of two major computer programs, ISC Short Term (ISCST) and ISC Long Term (ISCLT). The ISCLT model, an extended version of the Single Source (CRSTER) Model (EPA, 1977), is designed to calculate concentration or deposition values for time periods of 1, 2, 3, 4, 6, 8, 12, and 24 hours. ISCST can also calculate annual concentration or deposition value if used with a year of sequential hourly meteorological data. The ISCLT model is a sector-averaged model that extends and combines basic features of the Air Quality Display Model (AQDM) and the Climatological Dispersion Model (CDM). The long-term model uses statistical wind summaries to calculate seasonal (quarterly) and/or annual concentration or ground-level deposition values.

Since first being issued (Bowers et al., 1979), ISC Model has undergone several revisions to correct and improve the technical features of the model. Recent revisions to the UNAMAP version 6 covered in this addendum include an option to model receptors above ground level, and a refined treatment of building wake effects including the use of building dimensions as a function of wind direction.

2.0 DESCRIPTION OF MODIFICATIONS

a. Above-Ground ("flagpole") Receptors

With the release of UNAMAP version 6, the ISC Models (ISCST and ISCLT) still made the assumption that receptors were located at ground level. Even for elevated terrain, this assumption simplified the Gaussian equation considerably by reducing the number of multiple reflection terms by a factor of two. It also restricted the application of the model in complex site configurations from determining predicted concentrations above the ground, such as at intake vents and windows.

Both ISCST and ISCLT have been modified to permit the modeling of receptors above ground level as a user defined option, a feature that has heretofore only been available in RAM. When the option for above-ground receptors is selected, the model program expects to read user provided receptor heights, in meters, for all grid and discrete receptors. The formats used for input to the model are similar to the format used to input terrain elevations. The printed output format is also similar. Both height above ground (RHT) and terrain elevation (Z) at the receptor may be treated simultaneously.

Modifications to the code included expanding the vertical term to account for additional multiple reflection terms. Previously, the vertical term was defined in equation (2-42) of ISC the User's Guide as:

$$V = \exp[-0.5(H/\sigma_z)^2] + \sum_{i=1}^{\infty} \{\exp[-0.5(H_1/\sigma_z)^2] + \exp[-0.5(H_2/\sigma_z)^2]\} \qquad (1)$$

where:

Δh = plume rise

$H = h + \Delta h$

$H_1 = 2iH_m - H$

$H_2 = 2iH_m + H$

H_m = mixing height

The equation has now been expanded to:

$$V = 0.5 \left[\exp[-0.5(H/\sigma_z)^2] + \sum_{i=1}^{\infty} \{\exp[-0.5(H_1/\sigma_z)^2] + \exp[-0.5(H_2/\sigma_z)^2] + \exp[-0.5(H_3/\sigma_z)^2] + \exp[-0.5(H_4/\sigma_z)^2]\}\right] \quad (2)$$

where:

$H_1 = 2iH_m - H - RHT$

$H_2 = 2iH_m + H - RHT$

$H_3 = 2iH_m - H + RHT$

$H_4 = 2iH_m + H + RHT$

RHT = receptor height above ground

and the other symbols were previously defined.

The effective plume stabilization height H' of equation (2-44) of the ISC User's Guide, which is substituted for the effective stack height H in the vertical term at a point (X,Y), has also been modified to include the receptor height term as follows:

$$H' = H + Z_s - Z - RHT \quad (3)$$

where:

Z_s = stack base elevation above mean sea level

Z = terrain elevation above mean sea level

RHT = was defined above

Equation (2-45) of the ISC User's Manual was also modified to include receptors above ground when gravitational particulate settling occurs. The equation has been redefined as:

$$V = 0.5\,\phi_n \left[\sum_{i=0}^{\infty} (A_1 + A_2) + \sum_{i=1}^{\infty} (A_3 + A_4) \right] \qquad (4)$$

where:

ϕ_n = mass fraction of particulates in the n^{th} settling - velocity category

$A_1 = Y_n^i \exp\left[-0.5\left((H_1 + H_v)/\sigma_z\right)^2\right]$

$A_2 = Y_n^{i+1} \exp\left[-0.5\left((H_2 - H_v)/\sigma_z\right)^2\right]$

$A_3 = Y_n^i \exp\left[-0.5\left((H_4 - H_v)/\sigma_z\right)^2\right]$

$A_4 = Y_n^{i-1} \exp\left[-0.5\left((H_3 + H_v)/\sigma_z\right)^2\right]$

Y_n = reflection coefficient for particulates in the n^{th} settling - velocity category (Set equal to unity for complete reflection)

$H_v = V_{sn}\, x/u$

V_{sn} = settling velocity of particulates in the n^{th} settling - velocity category

Modifications to incorporate these changes in ISCST were performed in the MODEL and VERT subroutines of the program. Subroutine VERT compiles the summation term of the vertical term for gravitational settling categories. Subroutine DYOUT was also modified to allow printing of the receptor heights input. An additional subroutine VRTRHT was also created to calculate the exponential values of the vertical terms when receptors above ground level are present.

Modifications to ISCLT were performed in the MODEL and VERTC2 subroutines. Subroutine VERTC2 calculates the vertical term in the concentration equation when deposition is occurring. Subroutine OUTPT was modified to permit printing of the receptor heights input. Subroutine HEADNG was also modified to incorporate new page headers for "flagpole" receptors. An additional subroutine VRTC1R was also created to calculate the vertical term for the concentration equation when receptors above ground level are present. Subroutine VERTC1 which calculates the vertical term for the concentration equation was not modified to save computation time when "flagpole" receptors are not modeled. Note that these modifications do not apply when the model is run in the deposition mode since deposition is only calculated at ground level.

b. Revised Building Downwash Treatment

The original ISC Model in UNAMAP version 6 used a simplified downwash method to account for the effects of the aerodynamic wakes and eddies produced by plant buildings and structures. The adjustments for plume dispersion were made according to the suggestions of Huber and Snyder (1976) and Huber (1977) (the Huber-Snyder method). These suggestions were based on the results of wind tunnel experiments using a crosswind building width of two times the building height and a turbulence intensity between about C and D stabilities. The ISC Models applied either full building wake effect influence or none creating a physical discontinuity between the zones. The model also used only one set of building dimensions which described the expected downwash condition for the overall site. The ISCST model used the actual dimensions of the building to determine the equivalent circular area of the building, while the ISCLT model required the user the calculate and input the dimension of the equivalent square area. Thus, the model was constrained due to the limited data and research available.

The ISCST and ISCLT models have both been modified to include a refined building downwash treatment that uses a method based upon the suggestions of Schulman and Hanna (1986) and Scire and Schulman (1980) (the Schulman-Scire method). This method is designed to be used on either model when the regulatory default mode is selected or the building height on the source card is set to a negative value. (The negative sign is used as a flag to select the method.) The model performs the Schulman-Scire refined treatment for downwash only when the source height is less than or equal to the building height plus one-half of the lesser of the building height or projected width, otherwise the Huber-Snyder method is used.

When the Schulman-Scire downwash method is used by the model, a linear decay factor as a function of the effective plume height is applied. This is performed to bridge the physical discontinuity that exists between the wake region and the area beyond building downwash influence (see Figure 1). The linear decay factor, A, is determined as follows:

$$\text{If } H_e \leq h_b, \text{ then } A = 1 \tag{5a}$$

$$\text{If } h_b < H_e \leq h_b + 2L_B, \text{ then } A = [(h_b - H_e)/2L_B] + 1 \tag{5b}$$

$$\text{If } H_e > h_b + 2L_B, \text{ then } A = 0 \tag{5c}$$

where:

H_e = effective stack height

h_b = direction specific building height

L_B = minimum of direction specific building height or width

The decay factor is applied to the σ_z expression as:

$$\sigma_z = A[0.7L_B + 0.067\ (x-3L_B)] \text{ when } (3L_B < x < 10L_B) \tag{6}$$

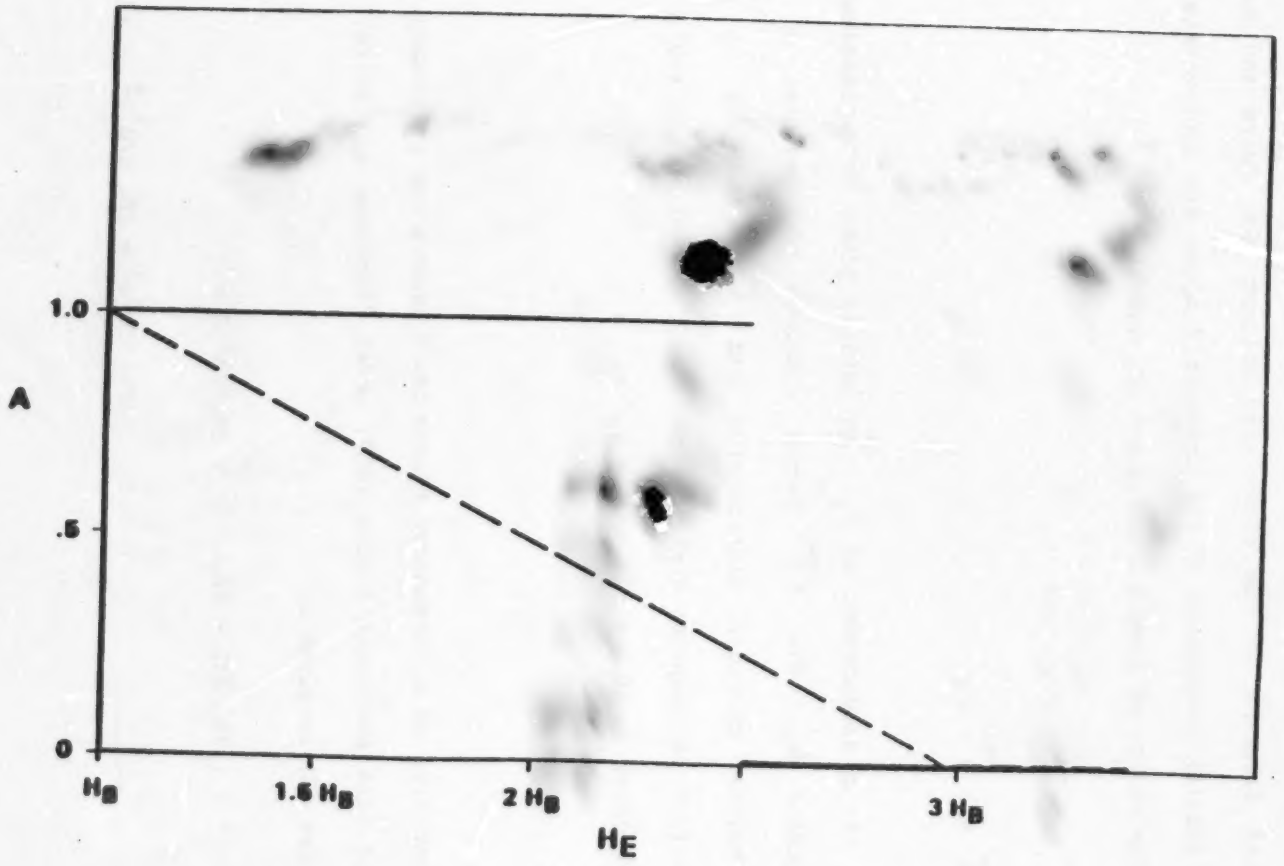


Figure 1-1 Linear Decay Factor, A, as a Function of Effective Stack Height, H_e. A squat building is assumed for simplicity.

which is the same as the original UNAMAP version 6 model except for the linear decay factor, A. The σ_y enhancement is only performed when $H_e \leq 1.2\ H_B$. The adjustment is only performed at plume heights for distances between H_B and $3H_B$.

In the Schulman-Scire downwash method, the plume rise is also modified due to the initial dilution of the plume with ambient air, Scire and Schulman (1980). The initial dimensions of the downwashed plume are approximated by a downwashed line source of length L and depth $2R_o$ where:

$$R_o = \sqrt{2}\ A\sigma_z;\ x = 3\ L_B, \text{ and} \tag{7}$$

$$YL = \sqrt{2\pi}\ \sigma_y;\ x = 3L_B \tag{8}$$

If there is no enhancement of σ_y, the initial plume is represented by a circle of radius R_o. The $\sqrt{2}$ factor converts the Gaussian σ_z to an equivalent uniform circular distribution and $\sqrt{2\pi}$ converts σ_y to an equivalent uniform rectangular distribution. Both σ_z and σ_y are evaluated at $x = 3L_B$, and because σ_z at $x = 3L_B$ equals $0.7L_B$,

$$R_o \cong AL_B \tag{9}$$

The buoyant rise of a downwashed finite point source was previously solved in the Buoyant Line and Point Source (BLP) model (Schulman and Scire, 1980). The neutral rise (Z) is given by:

$$Z^3 + (3L/\pi\beta)Z^2 + ((3R_o/\beta)Z + 6R_oL/\pi\beta^2 + 3R_o^2/\beta^2)Z =$$

$$3Fx^2/2\beta^2u^3 + 3F_m\ x/\beta_j^2u^2 \tag{10}$$

Maximum stable rise is calculated by:

$$Z^3 + (3L/\pi\beta)Z^2 + ((3R_o/\beta)Z + 6R_oL/\pi\beta^2 + 3R^2{}_o/\beta^2)Z = 6F/\beta^2uS \qquad (11)$$

where:

F = buoyancy flux term = $gv_sd^2(1 - T_a/T_s)/4$

F_m = momentum flux term = $(T_a/T_s)\ v_s^2d^2/4$

x = downwind distance

u = wind speed at emission height

β = entrainment parameter

β_j = jet entrainment coefficient = $(1/3 + u/v_s)$

v_s = stack exit velocity

d = stack diameter

T_a = ambient temperature

T_s = stack temperature

g = acceleration due to gravity

S = stability parameter

Direction specific building heights and projected widths are used as input to the model when both of the following criteria are met:

- The regulatory option is set or the building height is entered on the source and as a negative value; and
- $H_S \leq h_b + 0.5\ W_L$

  where:

  H_S = stack height of the source

  h_b = building height input to the model on the source card (variable HB) and,

  W_L = maximum projected building width

The direction specific dimensions are for every ten degrees centered at ten degrees in ISCST. In ISCLT, the direction specific dimensions are centered in every sector. The width in each sector or each ten degree "wedge" is the largest actual projected width of the overall building for that section.

The majority of the modifications were performed in the MODEL Subroutine of both ISCST and ISCLT where plume rise and wake effect treatments are executed. Additional changes were performed in subroutine INCHK of ISCST and subroutine OUTPT and HEADNG of ISCLT. Subroutine INCHK was modified to allow direction specific dimensions to be read, stored in the source array for later use, and printed as output for ISCST. In addition, two subroutines, BLP and CUBIC, were added for calculation of the buoyant plume rise.

In ISCLT, Subroutine OUTPT was modified to permit printing of the direction specific dimensions. Subroutine HEADNG was only modified to remove "ground level" from the header printed at the page top for concentration calculations.

3.0 MANUAL REVISIONS

Revisions to the manual appear as revised pages in the manual. Due to the extensive number of pages modified, only general changes will be described by section. One change made continuously throughout the ISC User's Manual was the removal of "ground-level" in describing concentration calculations. With the incorporation of receptor heights located above ground level, this term becomes irrelevant. However, the term is still applied when describing deposition calculations. The table of contents and other pretext pages have been modified to permit the listing of any new pages, tables, or figures inserted.

SECTION ONE

This section, which gives an overall description of both ISC models, was modified to include the general description of the two new additions to the model. Reference was also made to the Schulman and Hanna (1986) article as a third evaluation study of the ISC model. Table 1-1 was changed to include the new options. Figure 1-2 was altered to remove "ground-level" from the description for average concentration.

SECTION TWO

This section provides the mathematical and technical description of the model. Extensive changes were made especially to the sections on plume rise and dispersion coefficients when building downwash occurs. These were altered to permit the addition of a description of how the Schulman-Scire treatment method is applied. The section describing the vertical term was also changed to incorporate the addition of receptor height above ground to the mathematical equations and to the resulting description.

SECTION THREE

The description of the ISC Short Term model input options in Section Three was changed to include the addition of both new options. Explanations for the receptor heights above ground included the option switch, values the switch acknowledges, where the receptor heights are expected for input, and the input order. The description of the input requirements for the revised building downwash treatment includes the description of how the option is set with HB on the source card, where the model expects to read the direction specific dimensions, and the sequence by which they are input. Table 3-4 was also modified to include these new input variables. Table 3-8 was changed to include a new error message for the revised downwash treatment method. Brief diagnostic descriptions were also added to this table. The text was changed to include the addition of the three new subroutines, core storage requirements and output pages amounts.

SECTION FOUR

This section contains the input description and requirements for the ISC Long Term model. Changes were made in a manner similar to those in Section Three. Differences include adjustments to tape input and/or output as a result of new receptor height data and is reflected in Table 4-5. Figure 4-1 of the User's Guide was also changed to include the receptor heights above ground. The text was also changed in a manner similar to Section Three. Table 4-6, containing warning and error messages, was altered to include new messages resulting from the insertion of the revised building downwash method.

SECTION FIVE

Modifications to Section Five include the addition of several new references which were inserted to maintain alphabetical order.

APPENDICES

Changes were also made to Appendices A through H of the ISC User's Guide. Appendices A and B contain the new resequenced source code for ISCST and ISCLT, respectively. The modifications to Appendices C and D include a description of use of the new switches for two hypothetical modeling applications in ISCST and ISCLT, respectively. Figures in these appendices were also changed to reflect the new inputs to the models and printed outputs. Changes to Appendices E and F include the addition, sequence of execution, and description of the new subroutines in ISCST and ISCLT, respectively. Modifications to G and H, which include the respective FORTRAN coding forms for ISCST and ISCLT, include the additional switches and variable inserts for the new code modifications.

4.0 REFERENCES

Bowers, J.F., J.R. Bjorkland and C.S. Cheney, 1979: Industrial Source Complex (ISC) Dispersion Model User's Guide. Volume I, EPA-450/4-79-030, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711.

Bowers, J.F., J.R. Bjorkland and C.S. Cheney, 1979: Industrial Source Complex (ISC) Dispersion Model User's Guide. Volume II, EPA-450/4-79-031, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711.

Huber, A.H. and W.H. Snyder, 1982. Wind tunnel investigation of the effects of a rectangular-shaped building on dispersion of effluents from short adjacent stacks. Atmos. Environ. 176: 2837-2848.

Huber, A. H., 1977: Incorporating Building/Terrain Wake Effects on Stack Effluents. Preprint Volume for the Joint Conference on Applications of Air Pollution Meteorology, American Meteorological Society, Boston, Massachusetts.

Schulman, L.L. and S.R. Hanna, 1986. Evaluation of Downwash Modifications to the Industrial Source Complex Model. J. Air Poll. Control Assoc., 36 (3): 258-264

Schulman, L.L. and J.S. Scire 1980: Buoyant Line and Point Source (BLP) Dispersion Model User's Guide. Document P-7304B, Environmental Research and Technology, Inc., Concord, MA.

Scire, J.S. and L.L. Schulman 1980: Modeling Plume Rise from Low-Level Buoyant Line and Point Sources. Proceedings Second Joint Conference on Applications of Air Pollution Meteorology, 24-28 March, New Orleans, LA. 133-139.